3.G.2 f. (cont'd) differences in these standards, it must be remembered that assumed ambient temperatures reflect an opinion on the overall average or the typical or expected temperatures, not the range of temperatures that equipment may be expected to experience under all conditions of operation. It must also be remembered that although consensus opinions concerning a standard may change, the length of time it takes to implement those changes varies widely.

g. National Electrical Code. The National Electrical Code (NEC) indicates that for Code applications with Code wiring, the ampacity of the conductors connected to molded-case circuit breakers should be limited to that of 60 or 75 degrees Celsius wiring, even though the attached conductors may have a higher rating. Shipboard requirements in the Electrical Engineering Regulations do not impose this limit; such a limitation does not apply on ships and MODUs. Ship systems do not use Code wiring, and are not typical of common applications addressed by the Code. Cable constructed to the electrical engineering regulations have ampacities based upon rated conductor temperatures up to 100 degrees Celsius. Shipboard cables may be connected to circuit breakers without consideration of the NEC limitation.

3. Grounded Systems and Ground Detection (46 CFR 111.05).

a. Equipment Ground (46 CFR 111.05-3). The term "grounding" is often misunderstood due to use in several different concepts. A basic understanding of the various uses is important. There are three basic applications of "grounding" associated with safety of personnel or protection of electrical equipment. These are:

(1) The grounding of metal frames or housings of electrical equipment (chassis ground);
(2) The grounding of the neutral current-carrying conductor of an electrical distribution system; and
(3) The grounding of an electrical source of power in such a manner that the earth (or its substitute such as the hull) is used as a current-carrying conductor.

The first application is one of the most important uses of grounding to protect personnel from electric shock. Fixed equipment is usually grounded by its method of attachment to the vessel. Isolation mounted equipment is usually grounded by a flexible grounding strap between the enclosure and the hull. Portable equipment is usually grounded with a grounding conductor in the supply cable. This should connect the equipment housing to the vessel's hull. Under normal conditions, the housing is not energized. However, internal insulation breakdown or other failure can bring energized components in contact with the housing. If the housing were not grounded, the voltage on the housing could equal the voltage of the power source, and a person touching the housing would be exposed to this voltage. Grounding the equipment reduces the shock hazard. Conductors used to ground equipment are called grounding conductors. On an extension or portable tool cord, this is the green insulated conductor. Portable equipment such as power tools that are identified as "double insulated" need not have a grounding conductor in the attachment cord. These items have a basic (functional) insulation system and a supplemental (protective)

3.G.3 a. (cont'd) insulation system, with the two insulation systems physically separated so that they are not simultaneously subjected to the same deteriorating influences.

The second application is the intentional grounding of a single pole or terminal of the power supply of an electrical distribution system. This is accomplished by connecting a low resistance conductor from the pole to the ground (the hull).

The purpose of grounding one of the conductors is to limit the voltage that the system can be subjected to under certain fault conditions. Grounding can also be accomplished through a resistor (resistance grounding) or through an inductor (inductive grounding). In these methods, the resistor or inductor is used to limit the line-to-ground fault current; these require special considerations and analysis.

It is important that a grounded system have only a single point of connection to the hull, regardless of the number of power sources, and that it be accessible for inspection. Multiple grounding points could create potentially dangerous and damaging circulating currents through the hull. The neutral of each generation and distribution system must be grounded at the generator switchboard, except for the neutral of an emergency power generation system. This must have no direct connection to ground at the emergency switchboard. The emergency switchboard neutral bus must be permanently connected to the neutral bus on the main switchboard, and there must not be any fuse, switch, or circuit breaker that opens the neutral conductor of the bus-tie feeder.

Grounded distribution systems of less than 3000 volts line-to-line are prohibited on tank vessels by SOLAS. The concern is that fault currents going through the hull may cross discontinuities, such as riveted joints, ladders, etc., and there may be an arc and subsequent ignition of flammable vapors. Systems greater than 3000 volts may be grounded provided any resultant fault current would not flow through the cargo tank area. This is usually not a problem as electrical loads operating at these voltages (other than possibly a bow thruster) are typically not located separate from the machinery space.

On some merchant vessels, the electrical distribution systems are ungrounded. There is no intentional connection to ground. This is primarily for circuit reliability. The electrical system can sustain damage that "grounds" one of the conductors and still function (i.e. provide continuity of service).

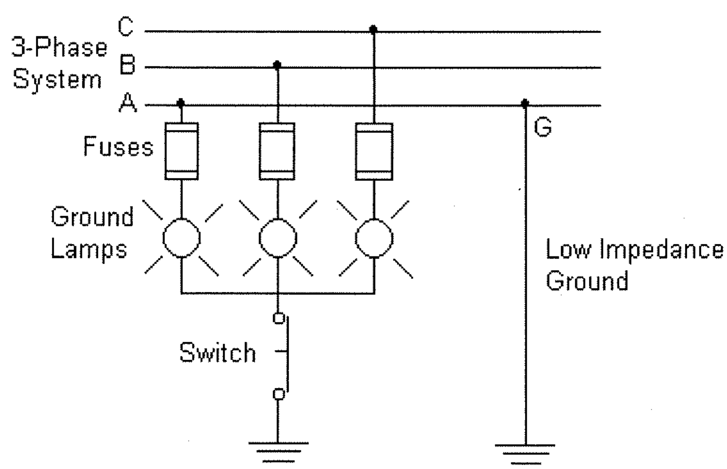
There is often the assumption that a person can contact an energized conductor in an ungrounded system, and not receive an electric shock since there is no return path for the current to flow back to the distribution system. Such an assumption can lead to fatal consequences. In practical applications, there is always a return path, and a system is always "grounded" to a certain extent. Paths exist through deteriorated or damaged insulation, and moisture, salt and other contaminants that are ever present. The issue is one of "degree." In ungrounded alternating current systems there is always a capacitance between conductors and between conductors and ground.

3.G.3 a. (cont'd) This impedance can effectively "ground" an intentionally ungrounded system.

The third application is the grounding of a power supply and an electrical load such that the hull is used as a normal current-carrying conductor. This is commonly referred to as "hull return" and is prohibited on vessels except for systems listed in 46 CFR 111.05-11. Acceptable examples include impressed current cathodic protection systems and limited and locally grounded systems such as engine cranking batteries. Insulation level monitoring systems and welding systems (on other than tank vessels) may also use the hull as a current-carrying conductor. One of the problems with hull return pertains to galvanic corrosion. Where the hull current passes through a welded joint or a joint of dissimilar metals, corrosion can occur.

b. Ground Detection (46 CFR 111.05-21, 23). Grounds can be a source of fire and electric shock. In an ungrounded system, a single ground has no appreciable effect on current flow. However, if low resistance grounds occur on conductors of different potentials, very large currents can result. In a grounded system, a single low impedance ground can result in large fault currents. To provide for the detection of grounds, the regulations require that ground detection means be provided for each electric propulsion system, each ship's service power system, each lighting system, and each power or lighting system that is isolated from the ship's service power and lighting system by transformers, motor generator sets, or other device. This indication need not be part of the main switchboard but should be co-located with the switchboard (i.e. at the engineering control console adjacent to the main switchboard). The indication may be accomplished by a single bank of lights with a switch which selects the power system to be tested, or by a set of ground detector lights for each system monitored.

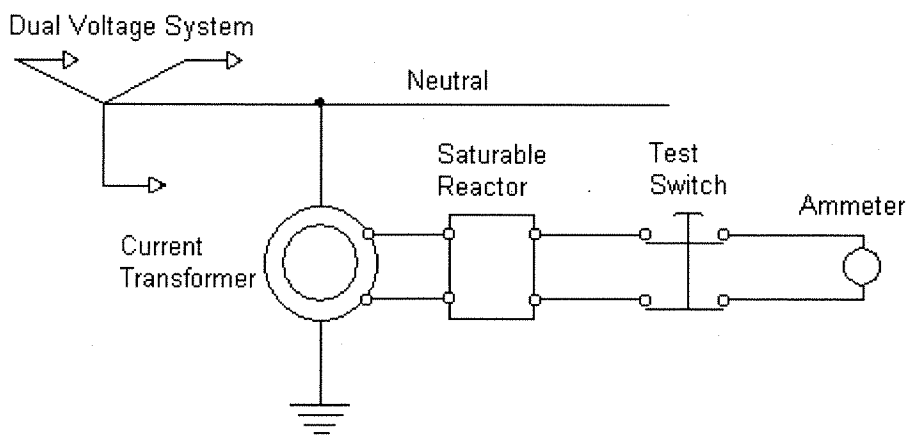
In an ungrounded three-phase system, ground detection lamps are used. The ground lamps are connected in a "wye" configuration with the common point grounded. A normally-closed switch is provided in the ground connection. This is illustrated in the figure below.



If no ground is present on the system, each lamp will see one-half of the phase-to-phase voltage and will be illuminated at equal

3.G.3 b. (cont'd) intensity. If line "A" is grounded at point "G" by a low impedance ground, the lamp connected to line "A" will be shunted out and the lamp will be dark. The other two lamps will be energized at phase-to-phase voltage and will be brighter than usual. If a low resistance ground occurs on any line, the lamp connected to that line will be dimmed slightly and the other two lamps will brighten slightly The switch is provided to aid in detecting high impedance grounds that produce only a slight voltage shift. When the ground connection is opened by the switch, the voltage across each lamp returns to normal (phase voltage) and each lamp will have the same intensity. This provides a means to observe contrast between normal voltage and voltages that have shifted slightly. Lamp wattages of between 5 and 25 watts when operating at one-half phase-to-phase voltage (without a ground present) have been found to perform adequately, giving a viewer adequate illumination contrast for high impedance grounds. Should a solid ground occur, the lamps will still be within their rating and will not be damaged. For lesser grounds, the lumen output of the lamps will vary approximately proportional to the cube of the voltage. This exponential change in lamp brightness (increasing in two and decreasing in one) provides the necessary contrast.

On grounded dual voltage systems, an ammeter is used for ground detection. This ammeter is connected in series with the connection between the neutral and the vessel ground. To provide for the detection of high impedance grounds with correspondingly low ground currents, the regulations specify an ammeter scale of 0 to 10 amperes. However, the meter must be able to withstand, without damage, much higher ground currents, typically around 500 amperes This feature is usually provided by the use of a special transducer such as a saturable reactor in the meter circuit. Some ammeters use a non-linear scale to provide for ease in detecting movement at low current values. An example of this is shown in the figure below.



Other types of solid-state devices are becoming available that can provide ground detection. They should not be prohibited, but should be evaluated to determine that they are functionally equivalent to the lights and ammeters historically used. Some systems also include a visual and/or audible alarm at a preset level of ground current.